RFID Expert's Corner

RFID Reader Antenna Basics – Polarization: Does it Really Matter?

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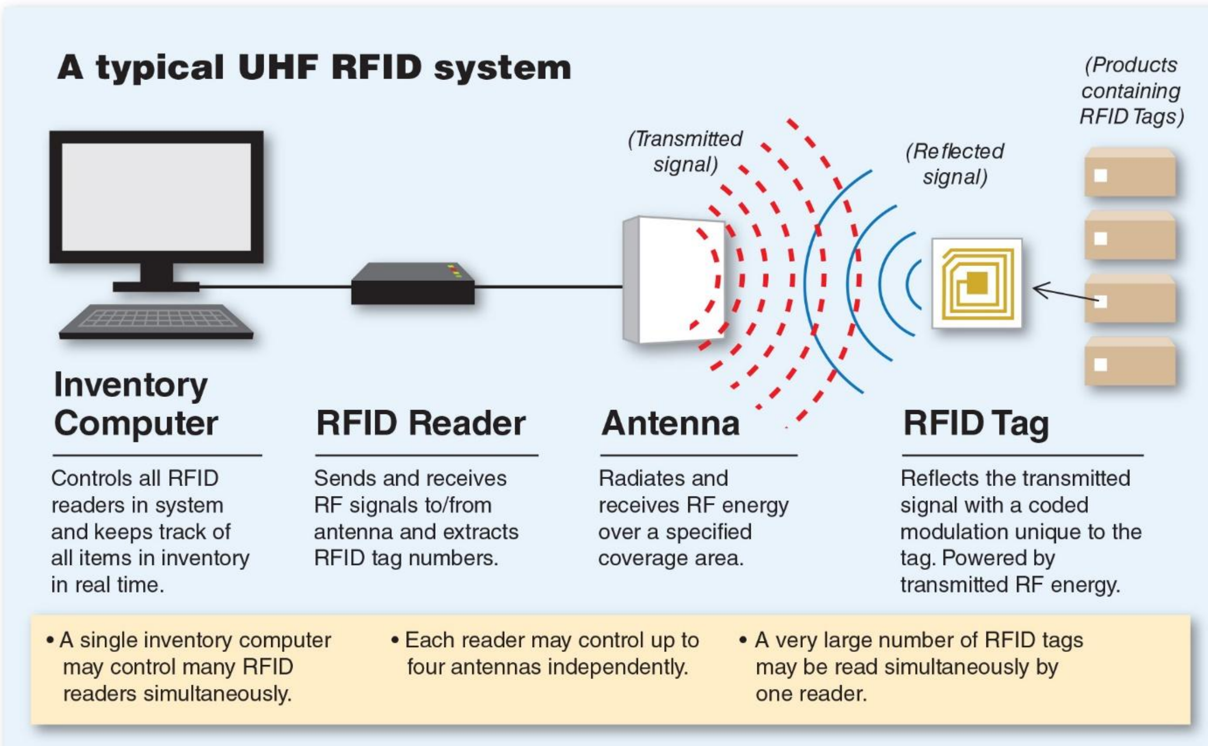
In a previous blog I maintained that the antenna is the most important part of a UHF RFID system (see figure below). This is because the computer software, reader, and RFID tag are fairly optimized now, and often outside the control of the system designer anyway. Performance improvements must come from the proper selection of the antenna and its deployment.



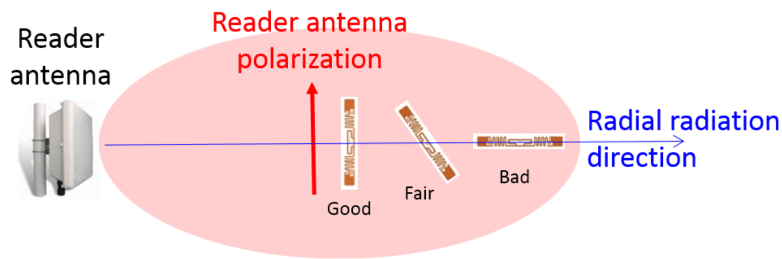
Before getting into the fine art of antenna deployment, it is first necessary to understand the basic principles of how antennas work and how the electromagnetic field radiated by an antenna fills and penetrates a given space. The main issues are polarization, fading, gain, EIRP (effective isotropic radiated power) and diversity. A good understanding of these issues will aid the designer in selecting the type and number of antennas, and where to put them for optimum performance.

To review, in the previous blog we explored the most basic characteristic of an antenna, namely, its **gain**. This number is defined as the directional amplification of the antenna compared with an antenna that radiates equally in all directions. Gain is closely related to **Effective Isotropic Radiated Power** (EIRP). EIRP is defined as the amount of power that a theoretical isotropic antenna would emit to produce the peak power density observed in the direction of maximum antenna gain. EIRP is limited by the FCC to 36 dBm (decibels relative to a miliwatt) of RF power. As we saw, because of this limit, it does not always help to use a high-

[1] The opinions expressed on this webpage are the author's and do not necessarily represent the opinions of The Ohio State University.

gain antenna because the EIRP will likely be exceeded unless the RFID reader power is reduced accordingly.

This brings us to the next important characteristic of an antenna: **polarization**. Polarization defines the predominant direction of the electric field radiated or received by an antenna. For a conventional antenna like the patch antenna, the polarization is always transverse to the direction of radiation outside the near-field region of the antenna. Therefore, the polarization of the receiving antenna (RFID tag) needs to be at least partially aligned with the polarization of the transmitting antenna, as illustrated below.



Alignment of the receiving antennas (RFID tags) relative to the polarization of the reader antenna (red arrow) and radiation direction (blue arrow).

In this example the patch antenna is linearly polarized in the vertical direction (red arrow). The RFID tags are dipole antennas which are also linearly polarized. From left to right, the first two tags will have a good received signal, but the last tag on the right will probably not be excited. Similarly, if the antenna is horizontally polarized (out of the page), none of these tags would be excited. This is the reason that tag read rates may not be optimized with patch antennas.

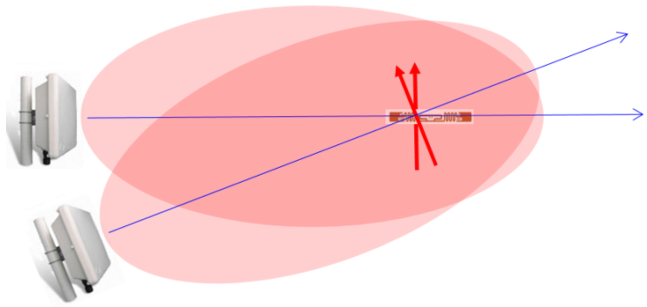
Circular polarization (CP) is a combination of vertical and horizontal polarizations with a phase difference of 90° between the two. CP antennas can read tags that are at least partially oriented in any plane transverse to the direction of radiation (blue arrow). For this reason, CP patch antennas are the most common in UHF RFID applications. There is a cost, however, because CP antennas have a 3 dB reduction in gain for reading linearly polarized tags. While the patch antenna has value in certain applications, this 40 year old technology is not optimal for item-level RFID solutions.

The radial direction away from the antenna is the worst possible orientation of a tag because it is orthogonal to both transverse directions. Using a linearly polarized or CP antenna will not help. This leads to our first principal:

1. *If a single antenna is used to read a large number of arbitrarily oriented RFID tags in a static scenario, a significant percentage will be unreadable.*

A "static scenario" is one in which there is no relative movement between the reader antenna and tags. Movement does help to improve reads, but only marginally if there are a lot of poorly aligned tags.

What is the obvious solution? Use more than one antenna as shown below. This introduces perhaps the most important concept in UHF RFID system design: **antenna diversity**. The figure illustrates **polarization diversity**. RFID readers typically have more than one antenna port for this reason. They cycle through the antennas to maximize the total number of reads in a given coverage area. If one antenna polarization is not aligned with all of the tags, it is likely that one of the other antennas is aligned.



*Two antennas provide **polarization diversity** for reading an RFID tag that a single antenna is not able to read due to the tag orientation.*

Our second principal is this:

2. *RFID antenna diversity is achieved by having more than one antenna covering a given area, maximizing the number of possible tag reads.*

In this blog we have introduced the concept of antenna diversity based on polarization diversity. The next blog will consider how antenna diversity overcomes another important concept in RFID system design, namely, **fading**.

Next blog: Antenna basics – overcoming fading with antenna diversity.